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INSTITUTE for MATHEMATICS and its APPLICATIONS

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December 16, 1994

Defense Technical Information Center
Building 5, Cameron Station
Alexandria, Virginia 22304-6145

Dear Sir/Madam:

Enclosed is the Final Technical Report on Grant N00014-94-0301, Emerging Applications of Probability (Stochastic Models in Geosystems). The Proceedings Volume for this grant is still in preparation. One copy of the proceedings will be mailed to you as soon it becomes available.

Sincerely,

Avner Friedman

Avner Friedman

cc: Ms. Virginia Olson, ORTTA

EMERGING APPLICATIONS OF PROBABILITY (STOCHASTIC MODELS IN GEOSYSTEMS)

FINAL REPORT

Period Covered by This Report: 1/1/94–7/31/94

AVNER FRIEDMAN

December 16, 1994

OFFICE OF NAVAL RESEARCH

Grant N00014–94–1–0301

INSTITUTE FOR MATHEMATICS AND ITS APPLICATIONS
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Grant N00014–94–1–0301 supported the research of US participants on Stochastic Models in Geosystems, part of the IMA 1993–94 program EMERGING APPLICATIONS OF PROBABILITY.

1. Description of Workshop (Stochastic Models in Geosystems)

The last decade has seen a massive infusion of sophisticated probabilistic and statistical tools in the geosciences, including geophysics, oceanography and geophysical fluid dynamics, and in atmospheric sciences. The workshop was devoted to several of the most active topics in this area and, in particular, covered:

- Probabilistic models in geophysics including hierarchical models for geophysical structures, homogenization of random elastic media, propagation of seismic waves, statistical methods for estimation of parameters of seismic waves, prediction problems for seismic phenomena and other geophysical fields.
- Modern probabilistic and statistical methods in oceanography and atmospheric sciences including: probabilistic and statistical mechanical models of large scale ocean circulation, random fields and stochastic partial differential equations techniques, waves in the ocean in presence of random topography and random forcing, random field modeling of salinity, temperature and other physical fields, weak turbulence. Prediction problems. Distribution functions for vorticity, velocity and dissipation rates. Intermittency and structure functions. Singularities in Euler equations and their relation to turbulence. Turbulent cascades and martingales.

2. Evaluations by the Organizers

Wojbor A. Woyczynski of Case Western Reserve University was an organizer for the workshops on *Stochastic Models in Geosystems* (May 16–20, jointly with Stanislav Molchonov) and on *Stochastic Methods for Nonlinear PDE's* (March 21–25, jointly with T. Funaki). He participated in IMA activity for five months of 1994. He is currently in the process of editing two IMA volumes containing proceedings of the two workshops that he organized. The first is entitled " Nonlinear Stochastic PDE's: Hydrodynamic Limit and Burgers' turbulence" (jointly with Funaki) and is in the final stages of preparation with 15 papers already deposited for final formatting at IMA and two in final stages of preparation by the authors. The second, entitled " Stochastic Models in Geosystems" (coedited with Molchanov), is about 70 percent complete. It will contain contributions from about 18 authors.

His report follows:

Workshop on STOCHASTIC MODELS IN GEOSYSTEMS:

Thirty three talks were presented by researchers from US, France, Canada, Great Britain, Russia, Italy, Ukraine, China and Lithuania, but many other scientists participated. Besides mathematics, they represented several disciplines including statistics, geology, oceanography, atmospheric sciences, physics and astrophysics. The major topics were turbulent diffusion and passive tracer transport in random velocity flows with applications to oceanic and atmospheric transport, stochastic forcing of oceanic motions, stochastic processes in Earth's litosphere, propagation of waves in random media and multifractal stochastic space-time models. The speakers provided an excellent overview of current research and several open problems were suggested. New contacts were established.

Concentration period on STOCHASTIC METHODS IN NONLINEAR PDE'S:

This was a more focused meeting concentrating on Burgers turbulence and hydrodynamic limit problems. Twenty presentations were given by researchers from US, Germany,Taiwan, Lithuania, Hungary, Japan, China and Russia. Actually, it was a working meeting in the sense that several current research projects in the area were being finished at IMA at the same time.

Interaction with leadership and staff of IMA:

This was an outstanding experience, a model (to be taken back to our home institutions) how well a broad mathematical activity can be organized . Mike Steele did all the background work carefully and selected right people to run individual projects. He was obviously the invaluable idea man for the special year. Avner Friedman has organized a seemless operation at IMA with strong apllied mathematics values where scientists from outside mathematics and from industry can collaborate with mathematicians on equal footing. He has to be credited with the outstanding research and pro(intyer)active atmosphere at IMA. The scope of the operation is obviously enlarged compared to what the reporter could observe in the mid-eighties. Willard Miller run the day-to-day operations with complete mastery of and attention to details. Devil in the details was firmly under control.

The staff was friendly, professional and consistently helpful.

Research interaction:

Woyczynski conducted a reserach program concentrated on the study of Burgers turbulence and on turbulent diffusion, including their applications in oceanography. He pursued a number of collaborative research projects with visitors at IMA and members of the Mathematics Department. Those included joint work

- with Stan Molchanov and Donatas Surgailis on hyperbolic scaling limits in Burgers turbulence,
- with Yiming Hu on shock density analysis for Burgers turbulence,

- with Tadahisa Funaki on nonlocal Burgers equation,
- with Craig Zirbel on rotation number for passive tracer transport for random velocity flows, and,
- with Sasha Saichev on probability distributions of passive tracers in randomly moving media.

The resulting manuscripts have either been submitted for publication or are under preparation. Also an opportunity for perhaps less formal research interaction with several IMA visitors (Mike Steele, Mike Harrison, Frank Kelly, Jim Dai, Ruth Williams, Malyshev, Misha Menshikov, Peter Jagers, Elena Krichagina) and members of the Mathematics and Statistics Departments (Larry Gray, NIck Krylov, Fedorov, Maurey Bramson and old friends like Naresh Jain, John Baxter, Bert Fristedt) and participation in their probability seminar was greatly appreciated.

For a couple of months Woyczynski was also responsible for organization of the twice-weakly IMA Seminar on Applied Probability.

Other workshops at IMA:

Woyczynski also participated in other workshops at IMA: Mathematical Population Genetics Workshop in January, Stochastic Networks Workshop in March, and Image Models Workshop in May. The first two had examplary organization and effective leaderships. Their influence extended beyond just the weeks when they were conducted as numerous participants (including the organizers - which was critical) stayed on for several more weeks creating a vibrant research environment. The third workshop felt more like a "one-night stand" variety although there were some good talks given.

3. Manuscripts Received for the IMA Proceedings Volumes on Stochastic Models in Geosystems, (workshop was held on May 16–20, 1994) Editors: Stanislav A. Molchanov and Wojbor A. Woyczynski

- Keiiti Aki, Seismic coda waves: A stochastic process in earth's lithosphere
- Robert Anderson, Limit theorems for one-dimensional random walk in a random environment
- L. Ju. Fradkin, A non-linear model for fluid parcel motions in the presence of many large and meso-scale vortices
- Roman Glazman, Theory and Observations of Wave Turbulence
- David Gurarie, Symmetries and conservation laws of two-dimensional hydrodynamics
- J.R. Herring, The role of statistical models in turbulence theory

- Greg Holloway, Ocean circulation: Flow in probability under statistical dynamical forcing
- V.I. Klyatskin and W.A. Woyczynski, Dynamical and statistical characteristics of geophysical fields and waves and related boundary-value problems
- W. Kohler, G. Papanicolaou and B. White, Localization of low frequency elastic waves
- Stanislav A. Molchanov, Spectral analysis of Lagrangian trajectories
- Peter Müller, Stochastic forcing of oceanic motions
- Pecknold-Lovejoy-Schertzer, New Modeling techniques for anisotropic scalar multifractals
- L.Piterbarg, Short-correlation approximation in models of turbulent diffusion
- Murray Rosenblatt, Comments on estimation and prediction for autoregressive and moving average nonGaussian sequences
- A.I. Saichev and W.A. Woyczynski, Probability distributions of passive tracers in randomly moving media
- Sergei Shandarin, Three-dimensional Burgers' equation as a model for the large-scale structure formation in the universe
- Daniel Schertzer, Advanced stochastic multifractals in geophysics: Lie cascades and multifractal phase transitions
- Hubert Shen, Non-mean field approach to self-organization of landforms via stochastic merger
- Richard Smith, Long range dependence and global warming
- P.L. Taylor and B. Lin, Modeling the spatiotemporal dynamics of earthquakes with a conservative random potential and a viscous force
- Ed Waymire, Random cascades and their applications
- P. Weichman, Spherical model of turbulence
- Craig L. Zirbel and Erhan Çinlar, Mass transport by Brownian flows

4. Manuscript Published in the IMA Preprint Series

1272 **V. Malkin & G. Papanicolaou**, On self-focusing of short laser pulses

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IMA NEWSLETTER # 215

May 1 - May 30, 1994

1994-95 Program
WAVES AND SCATTERING

News and Notes

University of Wisconsin, Madison joins the IMA

The University of Wisconsin, Madison has become an IMA Participating Institution (PI), effective April 10, 1994. There are now 29 PIs.

IMA Workshop:

Stochastic Models in Geosystems

May 16-20, 1994
Organizers: S. Molchanov and W. Woyczynski

Supported by the Office of Naval Research

The last decade has seen a massive infusion of sophisticated probabilistic and statistical tools in the geosciences, including geophysics, oceanography and geophysical fluid dynamics, and in atmospheric sciences. The workshop will be devoted to several of the most active topics in this area and, in particular, will cover:

- Seismology and disordered media— Probabilistic models in geophysics
- Oceanographic and atmospheric models— Modern probabilistic and statistical methods in oceanography and atmospheric sciences.

Monday, May 16

Unless stated otherwise, the talks today are in Conference Hall EE/CS 3-180

Morning Session Chair: W.A. Woyczynski

9-9:30 am	**Registration and Coffee** Reception Room EE/CS 3-176	
9:30 am	**Welcome and Orientation** EE/CS 3-180	
9:45 am	**K. Aki** University of Southern California	Seismic coda waves: A stochastic process in earth's lithosphere

Abstract: Seismic coda waves are a natural wonder. Because they are formed by scattered waves from numerous heterogeneities in the lithosphere, nature does the averaging over a large volume of the earth and leads to simple separability of the effects of seismic source, propagation path and recording site effects. In this review, we shall focus on the decay rate of coda amplitudes, called coda Q-1, and discuss its significance as a geophysical parameter characterizing regional structures and processes in the lithosphere.

10:45 am	**Coffee Break** Reception Room EE/CS 3-176	
11:15 am	**Greg Holloway** Institute of Ocean Sciences, Sidney B.C.	Ocean circulation: Flow in probability under statistical dynamical forcing

Abstract: The ocean has enormously more excited degrees of freedom than can ever be observed or ever held in any computer. Are efforts to predict, e.g., the role of oceans in climate change, doomed? Practical approaches consist of holding in computer models as many degrees of freedom as one can while consigning "the rest" to some manner of "eddy viscosity" (usually). This is thought to work (kinda sorta) as long as most of the velocity variance is contained in the model-resolved modes. Such resolution is only marginally possible on today's very most powerful computers, permitting only limited exploration, while the kinda-sorta aspect is threateningly unclear.

We are invited to rethink. If we only imagine defining the state of ocean in probability, appreciating uncertainty, then we may imagine predicting the probability of some future ocean. Practically, this may refer to predicting moments of a pdf for future (or even the present) ocean. This focuses our attention on the need for equations of motion of moments of pdf of possible oceans which turn out to be different from the equations of modelling business-as-usual. Especially, system entropy $[\int p \log p]$ appears, while gradients of entropy with respect to realized moments appear as generalized forces that drive equations for evolution of moments.

This view has been implemented, with a liberal degree of by-guess-and-by-golly, in context of conventional ocean models. Exercises have been performed from global scale down to estuarine. Some exciting differences emerge, possibly tending to "correct" certain long-standing problems of ocean modelling. Poleward undercurrents form along eastern ocean margins. Western boundary currents separate from coastlines more realistically. Excessive

implied air-sea heat and water exchanges are reduced. Subpolar gyres are strengthened. Etc. Are these actual successes or only happenchance pretty pictures? Critical attention is drawn to the by-guess-and-by-golly parts!

Afternoon Session Chair: S. Molchanov

2:00 pm	**Wojbor Woyczynski** Case Western Reserve U/IMA	Statistical and space-time characteristics of passive tracer fluctuations in randomly moving media

Abstract: We study probabilistic properties of fluctuations of density of the passive tracer and related random fields in a chaotically moving medium. This is done within the framework of diffusion approximation and Gaussian field of velocities Both compressible and incompressible cases are considered. Probability distributions of density fields and Jacobians are found for compressible media. Formulas relating statistical characteristics in Lagrangian and Eulerian coordinate systems are provided. For the incompressible medium statistical properties of the gradient field of the passive tracer and other related quantities are discussed.

Joint work with A. Saichev.

3:00 pm	**Massimo Vergassola** Observatoire de Nice, CNRS	Non-linear selection of cyclonicity in 2-D Navier-Stokes flows

Abstract: The large-scale dynamics of 2-D incompressible Navier-Stokes flows subject to small-scale forcing is discussed. Multiscale techniques are exploited to calculate transport coefficients, e.g. eddy-viscosities, and it is shown that the latter can become negative even in the isotropic case. Large-scale perturbations are then amplified in the linear regime and non-linear effects must be taken into account. For small-scale forcing lacking mirror-symmetry, the existence of a new chiral non-linearity is predicted. Large-scale vortices are then strongly enhanced or depleted depending on their cyclonicity.

4:00 pm	**Vincent Hall 502** (The IMA Lounge)	IMA Tea (and more!)

A variety of appetizers and beverages will be served.

**SEMINAR IN { Combinatorics
Vincent Hall 570**

4:40 pm	**Anne de Medicis** University of Minnesota	Combinatorial aspects of linearization coefficients of orthogonal Sheffer polynomials

Abstract: A sequence of polynomials $p_n(x)$ is called a sequence of Sheffer polynomials if their exponential generating function has the form $f(t)\exp(xg(t))$. Meixner showed that there exist only 5 classes of orthogonal Sheffer polynomials, namely the Hermite, Charlier, Laguerre, Meixner, and Meixner-Pollaczek polynomials.

We will discuss the combinatorial models for these polynomials, their moments, and their linearization coefficients. In particular, we present a new combinatorial proof of orthogonality and linearization coefficients for the Meixner polynomials.

If time permits, we will also give a combinatorial proof of a theorem of Askey on the positivity of linearization coefficients for general orthogonal polynomials, using the theory of Viennot.

Organizer: Viç Reiner

Tuesday, May 17

Unless stated otherwise, the talks today are in Conference Hall EE/CS 3-180

Morning Session Chair: D. Surgailis

8:30 am	**Y. Chigrinskaya** Universite Pierre et Marie Curie	Obukhov's cascade model of turbulence vs. shell models: Multifractal stochastic space-time intermittency, Lie structure and self-organized criticality

Abstract: Obukhov (1973) developed a dynamical space-time cascade model for a velocity component by considering the similar Lie structures of hydrodynamic equations (e.g. the vorticity equation) and Euler's equations of the gyroscope. By studying the most energetic path (Gluhovsky 1975a,b): the model reduces to a "shell-model" which may be obtained by some other direct phenomenological considerations (Gledzer, 1979). Although they are not able to give insights into spatial intermittency, shell-models became extremely popular, whereas the original full space time model was forgotten. On the contrary, we show that refined space-time vectorial cascade models can be derived by partial truncation of the direct interactions. We compare these (deterministic) dynamical models to (stochastic) multifractal multiplicative models of intermittency, determining their Levy index (a) of multifractality and critical order of first order phase transition (qD) which leads to the appearance of Self Organized Criticality.

Joint work with D. Schertzer S. Lovejoy, and A. Ordanovich.

9:00 am	**Peter Muller** University of Hawaii	Stochastic forcing of oceanic motions

Abstract: Most oceanic motions are forced by the atmospheric windstress and by the atmospheric heat and fresh water fluxes. Part of these atmospheric forcing fields are of a stochastic nature due to inherent instability and turbulence mechanisms within the atmosphere. Simple stochastic forcing models have been successful in describing a variety of oceanic phenomena, including the variability of the mid-latitude sea surface temperature, subinertial barotropic currents and the internal gravity wave field. These simple stochastic forcing models are based on Langevin's equation. The random forcing and the feedback parameter are either determined by fits observations or rationalized by a stochastic model of the relevant atmospheric fluctuations and a dynamical model of the ocean. These simple stochastic forcing models are reviewed. Then the stochastic forcing of oceanic quasi-qeostrophic eddies is considered. Coherence maps describe the coherence between the oceanic response at one location and the atmospheric response at another location as a function of separation for different frequencies. It is shown that a simple stochastic forcing model can account for the basic features in observed coherence maps. It especially accounts for the qualitative changes that occur when different oceanic variables are considered or when the frequency is changed.

10:00 am	**Coffee Break** Reception Room EE/CS 3-176	
10:30 am	**Richard Smith** University of North Carolina	Long-range dependence and global warming

Abstract: One of the major problems of climate research is to distinguish between trends that may represent some real change in the climate, such as global warming, and natural long-term fluctuations. A statistical approach to this question may be adopted by representing the data as a sum of a trend and a stationary process with long-range dependence, and then testing for significance of the trend component. In this talk I shall review some published work on this topic (Smith 1993) and shall also relate it to recent theoretical work of P.M. Robinson on spectral density estimation in long-range-dependent processes (Robinson 1993). Then I shall outline some work currently under development concerning the extension to spatial-temporal processes. The topic includes a number of unresolved theoretical issues as well as questions of an important practical nature.

References:

Robinson, P.M. (1993), Log-periodogram regression of time series with long-range dependence. Preprint, London School of Economics.

Smith, R.L. (1993), Long-range dependence and global warming. In "Statistics for the Environment" (V. Barnett and F. Turkman, eds.), John Wiley, Chichester, pp. 141-161.

11:30 am	**Shaun Lovejoy** McGill University	Generalized scale invariance and universal multifractals: A stochastic self-organized critical framework for geophysics

Abstract: Geophysical processes are typically highly intermittent, displaying both extreme variations in intensity at fixed scales as well as complex (multi)fractal structures over wide ranges. Conventional approaches for dealing with such processes are typically deterministic, involving nonlinear partial differential equations. A tradition which is still popular studies various linearisations of the system, or attempts to reduce them to ordinary differential equations. More recently, the latter have been studied by (low dimensional) chaotic approaches, but these ignore the spatial structures, and this approach is loosing appeal. A recent approach ("classical" Self-Organized Criticality, SOC) recognizes the importance of the structures, but up until now has unfortunately been tied to deterministic models with unrealistic features (particularly the "zero flux" constraint on their temporal boundary conditions). We argue that the preoccupation with deterministic models is a philosophical prejudice and that the appropriate framework for these large-number-of-degrees-of-freedom system is generally stochastic, and in in particular, in geopysical systems actually a (nonclassical) stochastic multifractal SOC. Furthermore, since scale invariance is a symmetry principle; a priori geophysics involves interacting dynamical (stochastic) multifractal processes. While scaling must be our initial assumption (scale breaking mechanisms should only be introduced when necessary) the further (increasingly common) assumption of self-similar (or self-affine) geodynamics is both unrealistic and unnecessary. These simplistic notions of scaling can lead to the false identification of breaks, and they are fundamentally incompatible with the observed richness of geophysical structures. In order to fully exploit scale invariance and to simulate and analyse geophysical scaling systems over wide ranges in scale, the general framework of Generalized Scale Invariance (GSI) is required.

However, geophysical fields not only have structures at all scales, they are also found at all intensities, involving multifractal fields rather than geometric fractal sets. While at first sight it may seem that the original simplicity of the fractal aproach is lost since multifractals generally involve an infinite number of parameters. However, due to the existence of multifractal universality classes, we argue that only three parameters are physically relevant: a, the index of multifractality, C1, the sparseness of the mean field, and H, the degree of nonconservation of the process. Depending on the dimension of the observing space, there is a further parameter (qD) which characterizes the self-organized critical structures associated with extremely violent events. In this talk, we recall the basic features of GSI and universal multifractals, and survey recent relevant studies in turbulence, rain, clouds, radiation, topography, geomagnetism surfaaces, measuring networks, speech, and river flows. Finally we indicate how to perform the relevant stochastic simulations.

Joint work with D. Schertzer)

Afternoon Session Chair: R. Smith

2:00 pm	**Peter Baxendale** University of Southern California	Rates of mixing for the transport of a passive scalar by a stochastic flow

Abstract: We consider the transport equation for a scalar $S(x,t)$ driven by a (random) incompressible velocity field $V(t,x)$ and with diffusivity constant k, where the velocity field V is assumed to be delta correlated in time (but smoothly correlated in space). Thus the underlying Lagrangian flow may be regarded as a stochastic flow of diffeomorphisms on the state space, and the transport equation is a (white noise) stochastic partial differential equation. We use the representation for $S(t,x)$ in terms of an associated stochastic flow to obtain large time estimates on the covariance of $S(t,x)$ and $S(t,y)$. In particular we consider the relative effects of large time, small $||x-y||$, and small diffusivity k in an attempt to illustrate the connections between the characteristic time and length scales of the flow.

3:00 pm	**Coffee Break** Reception Room EE/CS 3-176	
3:15 pm	**Roman Glazman** California Institute of Technology	Spectra of sea surface height variations in the absence of scale invariance

Abstract: Wave turbulence is a common property of oceanic wave motions, observed on scales from wind-induced surface capillary-gravity ripples and to those of inertia-gravity and Rossby waves. In general, oceanic wave motions are characterized by rather complicated dispersion laws which contain characteristic scales, such as the Rossby radius of deformation, etc. The resultant absence of scale invariance makes many problems of wave turbulence intractable by standard mathematical techniques (such as the kinetic equation approach known as the weak-turbulence theory). As a result, present theoretical understanding of wave turbulence has been limited

to short- or long-wave asymptotic regimes. Another, more fundamental, limitation of the present (perturbation-based) theories is the inevitable assumption of a small wave amplitude. A number of laboratory (wave tank) and field (satellite altimeter) measurements reveal certain important features of ocean wave spectra that cannot be explained by scale-invariant and/or weak-turbulence theories. Based on a recently developed ("multiwave-interaction") heuristic approach, we report analytical results for non-scale-invariant cases including capillary-gravity ripples and inertia-gravity waves in a rotating ocean. The predicted spectra of a (not necessarily weak) wave turbulence are compared with the observed spectra showing remarkably good agreement.

4:15 pm	**David Gurarie** Case Western Reserve University	ON statistical hydrodynamics in 2D

Abstract: We discuss the hamiltonian structure, conservation laws and the equilibrium statistical ensembles for the 2-D Euler equation and its variations: Navier-Stokes, Quasigeostrophic flow over deterministic or random topography. Equilibrium ensembles describe asymptotic states of the hydrodynamic systems with large numbes of excited modes (turbulent states) in the absense of external forces and dissipation. The standard approach to 2-D turbulence (Kreichnan) is based on the notion of the Gibbs ensemble, based on the energy, enstrophy and other conserved integrals. There is no however a satisfactory explanation or derivation of the proper Gibbs law from the underlying hydrodynamic equations. The nature of 2-D hydrodynamics (and its conserved integrals) will be elucidated in the language of certain infinite Lie algebras and degenarate hamiltonian systems. We then propose an approach to both deterministic and statistical equilibria using the direct eigenmode interaction expansion and exploiting the Lie algebra structure constants. Some preliminary results, examples and open problems will be outlined.

Wednesday, May 18

Unless stated otherwise, the talks today are in Conference Hall EE/CS 3-180

Morning Session Chair: P. Mueller

8:30 am	**Frank W. Elliott, Jr.** Princeton University	A new Monte Carlo method for turbulent diffusion with many scales

Abstract: We begin with an overview of the work of Horntrop and Majda on exactly solvable advection diffusion problems and the performance of standard random field simulation algorithms in solving these problems. Noting the limitations of these algorithms in simulating random fields over many spatial scales with low variance, we present the work of Elliott and Majda on a new Monte Carlo algorithm for computing stationary, isotropic, Gaussian vector fields with infrared divergence. Using a decomposition of the field into *plane waves* (one-dimensional fields) and a wavelet expansion of each plane wave, the new algorithm simulates the field with low variance and at a computational cost which is logarithmic in the ratio of the largest to the smallest scale. Specifically, when we simulate a two-dimensional, incompressible, isotropic, Gaussian vector field with the Kolmogoroff spectrum by our method, we find that the velocity structure function

$$\left\langle (v(x'+x)-v(x'))^2 \right\rangle = C|x|^a$$

is accurate over *twelve decades* while using only 46,592 active computational elements. With only 100 realizations of the field, the error in the scaling exponent, a, is 1.1% and the error in the constant prefactor, C, is 6%. In fact, for 10 realizations of the field, the error in the exponent is within 3.3% Finally, we briefly compare our hierarchical method with an often- used hierarchical method.

9:00 am	**Sergei Shandarin** University of Kansas	Three-dimensional Burgers' equation as a model for the large scale structure formation in the Universe
10:00 am	**Coffee Break** Reception Room EE/CS 3-176	

10:30 am	**Jackson R. Herring** NCAR	Statistical models of turbulence and their implications for large-eddy simulations

Abstract: The statistical theory of turbulence (SST) consists of evolution equations for two-point ensemble-mean covariances (in space and time) of the turbulent velocity and temperature fields, $U(x,x';t't') \equiv \langle u(x,t)u(x',t')\rangle$. On the other hand, large eddy simulation methods (LES) seek closed equations for large-scale averaged (or filtered) fields, with the small scales eliminated via some plausible closure hypothesis. LESs are indispensable in atmospheric flows, for which the Reynolds number is large and the task of implementing the SST is formidable. We will explore a possible connection between SST and LES. We first note that at large Reynolds numbers, it is possible to prescribe plausible eddy-dissipation formulas which involve little empiricism. From the perspective of SST, such a prescription would contain little information related to higher-order cumulants. We argue that, granted the statistical unpredictability of the equations of motion, such may well be case for any LES. Thus the only plausible interpretation of LES: the large-scale eddy-averaged field is a typical configuration of eddies to be found in developed turbulence. On this basis, we should expect a high degree of correlation between direct numerical simulation DNS and LES fields only at the variance level: $\langle u(x,t)u(x',t')\rangle$ should be similar.

We will sketch the structure of the statistical models that underlie the SST, noting their limitations, with regard to both accuracy and the technical difficulty in their implementation for practical problems. The major point to be discussed here is the inability of such theories to properly represent the effects of intense small-scale structures, whose statistics are far from Gaussian. We will focus on the problem of how an initially random state evolves towards a possible finite time vorticity singularity in order to display in stark terms the difficulties the statistical approach has in coping with structures.

Finally, we will comment upon recent attempts to incorporate "backscatter " into LES prescriptions. Such methods seek to include, by random perturbations, the effects of small scales (which are not explicitly included in LES) on those scales that are retained explicitly.

11:30 am	**Stanislav A. Molchanov** University of North Carolina	Spectral analysis of Lagrangian trajectories

Abstract: Let $\vec{V}(t,x)$ be an Eulerian velocity field on the plane with standard properties (homogeneous in space and time, Gaussian, incompressible, markovian in time, etc.) The Lagrangian (drifter) trajectory X_t is the solution of SDE

$$dx_t = \sigma dw_t + \vec{V}(t,x_t)dt.$$

We'll prove a few mathematical results about the statistical properties of the Lagrangian trajectory and the Lagrangian velocity $\vec{\mathcal{V}}(t) = \vec{V}(t,x_t)$ including a new nonlinear equation for the spectrum of $\vec{\mathcal{V}}$. The proofs are based on a new form of stochastic anticipating integrals with multidimensional time.

Afternoon Session Chair: J. Herring

2:00 pm	**Leonid Piterbarg** University of Southern California	Turbulent diffusion

Abstract: How can one describe the behavior of apassive scalar advected by an unsteady random velocity field? This problem is extremely important in the study of interchange process in the ocean due to eddy turbulence. The present work is an effort to review and classify some of the exactly solvable models of random transport proposed since the classical paper of Taylor, 1921. Our focus is on the "short-correlation" or "diffusion" approximation which suggests that the correlation time τ_E of the velocity field is small compared to both the current time and the molecular diffusion time. The answer to the stated question depends drastically on the relation between τ_E and the turnover time τ_T which is the quotient of the space correlation scale and the mean squared value of the velocity. Some other asymptotical cases are discussed too.

3:00 pm	**Coffee Break** Reception Room EE/CS 3-176	
3:15 pm	**Aleksander Saichev** University of Nizhni-Russia	Dynamic and statistical properties of Burgers' turbulence in presence of random forces

Joint work with W.A. Woyczynski.

4:15 pm	**P. Weichman** Caltech	Spherical model for turbulence

Abstract: I develop a large-N method for the problem of homogeneous turbulence. The spherical ($N \to \infty$) limit yields Kraichnan's DIA equations. Implications for real turbulence ($N = 1$) are discussed. In particular, it is argued that the renormalization group results obtained by setting the expansion parameter $y = 4$ are incorrect, and that the Kolmogorov exponent has a nontrivial dependence on N, yielding 3/2 in the large N limit. This value is remarkably close to the experimental result, 5/3, which must therefore result from higher-order corrections in powers of $1/N$.

Thursday, May 19

Unless stated otherwise, the talks today are in Conference Hall EE/CS 3-180

Morning Session Chair: Greg Holloway

8:30 am	**Cathrine Naud** Universite Pierre et Marie Curie	Analysis and simulation of radiative transport in multifractal disordered media

Abstract: Considering an inhomogeneous medium, described within a multifractal framework, we characterize the induced inhomogeneity of the radiation field propagating through it, determining the relationships between their respective orders of singularities (g) and their associated codimensions ($c(g)$). We present new analytical results in the case of a multifractal plane-parallel atmosphere considering the conserved flux (F), the total radiance (J) and the RK-integral R. If we introduce inhomogeneity along the horizontal too, we get a $2-D$ case and we compare with the previous results. We use simple radiative models, respecting the above characteristics and demonstrate that the radiation and clouds fields have the same type of intermittency, focusing on the Levy index a of multifractality ($02a22$: $a = 0$ corresponds to the monofractal b-model, $a = 2$ corresponds to the maximum of universal multifractality).

Joint with D. Schertzer and S. Lovejoy

9:00 am	**Murray Rosenblatt** UC San Diego	Parameter estimation and prediction for nongaussian solutions of difference and differential equations

Abstract: Remarks are made indicating how parameter estimation for nongaussian solutions may in certain circumstances differ radically from that for Gaussian solutions of difference equations or moving average schemes. The circumstances depend on whether a minimum phase condition is satisfied. Similarly the question whether a best predictor in mean square is linear or not depends on whether this condition is satisfied.

10:00 am	**Coffee Break** Reception Room EE/CS 3-176	
10:30 am	**A.M. Yaglom** MIT/Inst of Atmospheric Physics, Moscow	Statistics of small-scale fluctuations in fully developed turbulence

Abstract: The study of small-scale structure of developed turbulence was begun by Kolmogorov, who in 1941 proposed two similarity hypotheses postulating the universality of this structure. All the early experimental attempts to verify the hypotheses were performed in atmospheric and oceanic flows having especially high values of the Reynolds number. The experiments revealed some systematic deviations from Kolmogorov's predictions, which forced Kolmogorov and Obukhov to introduce in 1962 some significant corrections to the old theory. These corrections imply close connection of the small-scale structure to the statistics of the energy dissipation rate.

The ideas introduced in 1962 gave rise to enormous subsequent literature that completely changed the old ideas about the nature of developed turbulence. Many sophisticated models were proposed for the statistics of small-scale fluctuations, which shed new light on the intermittency effects, widely used new notions of fractality and

multi-fractality and expand considerably the class of practically important probability distributions. Theoretical studies of the intermittency of turbulence were supplemented by physical and numerical experiments leading to some interesting new discoveries. Short description of this development will be given in the talk.

SEMINAR IN { **Numerical Analysis**
Vincent Hall 570

11:15 am	**Petr Kloucek** University of Minnesota	Computational modeling of the martensitic transformation

Mitch Luskin, Organizer

11:30 am	**Benjamin S. White** Exxon	Localization and mode conversion for elastic waves in randomly-stratified media

Abstract: This work is in collaboration with W. Kohler and G. Papanicolaou. Localization is the phenomenon whereby a time-harmonic wave cannot penetrate a random medium, but is attenuated exponentially with propagation distance solely by the mechanism of random multiple scattering. In particular, when localization occurs, the exponential attenuation length, or localization length, is deterministic, that is, it has the same value for any realization of the random medium. Although originally investigated in the context of electrons, much interest has been generated recently in the localization of classical waves, and related concepts.

Localization theory for plane-stratified media has been applied to geophysical problems in the context of an acoustic model. It has been shown that under certain hypotheses the localization length as a function of frequency predicts the power spectra of backscattered pulses used to probe the medium, and localization lengths in the Earth have been estimated from well log data.

In this work, we derive localization theory for elastic waves in plane-stratified media, a multimode problem complicated by the inter-conversion of shear and compressional waves, both in propagation and in backscatter. In the low frequency limit, i.e. when the randomness constitutes a microstructure, we give analytical expressions for the following quantities: the localization length, and another deterministic length, called the equilibration length, which gives the scale for the equilibration of compressional and shear energy in propagation; the probability density of the fraction of reflected energy which remains in the same mode (shear or compressional) as the incident field; and the probability density of shear to compressional energy in transmission through a large slab. This last quantity is shown to be asymptotically independent of the incident field. Our main mathematical tools are: The Oseledec theorem, which gives the existence of the localization length, and other structural information; and limit theorems for stochastic differential equations with a small parameter.

Afternoon Session Chair:A. Yaglom

2:00 pm	**Craig L. Zirbel** IMA	Mass transport by stochastic flows

Abstract: A stochastic flow on R^d is a collection $\{F_{s,t} : 0 \leq s \leq t\}$ of random maps from R^d to R^d satisfying various regularity and composition properties. We consider a flow satisfying the stochastic differential equation:

$$dF_{0,t}(x) = u_0(F_{0,t}(x))dt + \sum_{k=1}^{\infty} u_k(F_{0,t}(x))W_k(dt)$$

Here $u_0, u_1, \ldots$ are deterministic vector fields and $W_1, W_2, \ldots$ are independent Wiener processes. Under this flow, the trajectory of an individual particle is a diffusion process. Two particles move in concert when close together, but diffuse independently when far apart. Such flows have been studied by Kunita, Harris, Baxendale, and others.

At time 0 a mass distribution M_0 is released into the flow. Its location at time t is given by a random measure M_t. We are interested in the behavior of the center of mass of M_t and the amount of spreading relative to the center of mass as $t \to \infty$. We consider the special case of isotropic flow. Our results depend critically on the spatial

dimension and the top Lyapunov exponent of the flow. The proofs rely on a careful study of a one-dimensional diffusion process.

Joint work with Erhan Cinlar.

3:00 pm	**Coffee Break** Reception Room EE/CS 3-176	
3:15 pm	**Larissa Fradkin** Cambridge University	Examples of Lagrangian turbulent diffusion

Abstract: It is well known that the turbulent diffusion may be analysed using two different approaches, one involving test particles and the other, the dynamically passive convected field. The particle approach is Lagrangian in character.

In this connection three non-linear parameter regimes have been studied analytically in the literature so far:

1. the quasi-linear regime (better known as the first-order smoothing or mixing length approximation), $\lambda \ll 1$;
2. the weakly non-linear almost Gaussian regime, $1 \leq \lambda \leq \lambda_o$; and
3. the strongly non-linear regime, $\lambda \geq \lambda_1 \gg 1$,

where the non-linearity parameter $\lambda \equiv A/c$, A is related to the particle correlation time and and c to the eddy turn-over time.

We start this talk by discussing our analytical approach that is applicable to a pretty wide class of stationary and non-stationary Eulerian fields in which particle displacements are distributed in a roughly Gaussian manner - at least on larger scales, and the parameter regime is weakly non-linear. We offer a refinement of the classical version employing a new type of the independence hypothesis, a Gaussianity-implying hypothesis and a new diffusion hypothesis.

We then move on to an interesting example of the non-stationary Eulerian field which is a result of a random superposition of harmonic waves moving in different directions with the same linear phase speed. We show that in the velocity fields of these nature, when intermediate spatial and time scales are considered, a non-Gaussian closure-like hypothesis should be introduced and assuming the particle displacements obey a Levy-like distribution accounts for many qualitative features observed in relevant oceanographic and numerical experiments.

4:15 pm	**Daniel Schertzer** Universite de Paris VI	Advanced stochastic multifractals in geophysics: Lie cascades and multifractal phase transitions

Abstract: We discuss two rather recent developments in stochastic multifractals notions and techniques. In order to grasp geophysical complexity, one not only needs to consider processes which are far beyond te original scalar framework of turbulent cascades, but also to understand qualitatively their transitions from one type of behavior to another.

On the one hand, a wide variety of possible multifractal behaviors exists ranging from extremely "soft" to "hard". More recently, it has been shown that they correpond to multifractal analogues of phaes, with two types of phase transitions. High or low temperature second order transitions naturally arise from finite sample sizes and are only representative of these limitations. In contrast, low teperature first order transitions are consequences of the scale and dimension of the observations which are no longer able to smooth down the most extreme small scale fluctuations building up larger scle structures. The latter is a generic (stochastic) route to non classical self-organized criticality, since it occurs in high dimensional (i.e. stochastic) multifractal processes with nonvanishing input (e.g. flux of turbulent energy).

On the other hand, the present situation is rather paradoxical: classical methods, such as those used in GCM modeling or direct simulations, deal easily with this vectorial interaction but only over very limited range of scales, whereas scaling models deal easily with an infinite range of scales but avoid to treating this vectorial interaction. For instance, multifractal modeling of clouds has rlied until now on the simplifying hypothesis that the interaction between the cloud and the dynamics can be reduced to a scalar relationship (namely between their respective fluxes).

However, a rather general framework of "Lie cascades" has been recently developed to analyze and generate multiplicative processes for vector and tensor fields, and more generally rather abstract fields admitting a Lie group of symmetries. This framework opens up a scalin and vectorial alternative to GCM techniques, since we then may consider the generator of the (scaling) multi-component field describing atmospheric states (e.g. dynamics, temperature, water concentraion, radiative fields, etc.). Not only this is very appealing on the theoretical level, it also allows rather direct analysis of the empirical data thanks to techniques such as 'Lie adjoint analysis' leading to an orthogonal decomposition of the generator of the joint field.

In conclusion, we emphasize that these two aspects of new developments of multifractals allows us to simulate and analyze both qualitatively and quantitatively a wide variety of geophysical fields and interactions, well beyond deterministic frameworks.

Joint work with S. Lovejoy.

5:45 pm	**Workshop Dinner at the Campus Club**	Coffman Union, 4th Floor,

Reservations required. Wine and cheese will be available in the Campus Club Lobby starting at 5:45. We go through the dinner line at 6:30. Dinner will be in the West Wing.

Friday, May 20

Unless stated otherwise, the talks today are in Conference Hall EE/CS 3-180

Morning Session Chair: S. Lovejoy

8:30 am	**Donatas Surgailis** Michigan State U/Inst. of Mathematics, Vilnius	Large-time asymptotics of statistical solutions of Burgers' equation

Abstract: Large-time asymptotics of rescaled solutions of Burgers' equation with stochastic initial condition is considered, with the emphasis on intermittency effects and shock-wave formation. Connections with the extremal theory of Gaussian and Poisson random fields are discussed, together with some open problems. The talk is based on joint work with A. Albeverio, S. Molchanov and W.A. Woyczynski.

9:00 am	**George Papanicolaou** Stanford University	Pulse reflection from locally layered random media

Abstract: We have studied extensively reflection of acoustic wave pulses (plane and spherical) from randomly layered random media. In this lecture we will discuss the extension of these results to random media with non-planar layering. More specifically, the mean variations of the medium can be fully three dimensional but the random fluctuations are one dimensional, along non-planar foliations. We discuss the role of localization in this setting and its physical implications.

This is joint work with Werner Kohler and Benjamin White

10:00 am	**Coffee Break** Reception Room EE/CS 3-176	

10:30 am	**V.I. Klyatskin** Institute for Atmospheric Physics, Moscow	Statistical characteristics of geophysical fields and waves

Abstract: Statistical characteristics of the geophysical fields and waves in a random media often differ considerably from the field behavior in separate realizations. Moreover, it appears that practically in each specific realization of the process one can be observed some characteristics of the process, that are completely absent in its statistical

description. In the simplest case such features are described by the lognormal probability law. We shall illustrate suchfeatures of statistical solutions by a few examples such as parametric stochastic resonance, the dynamical and statistical localizations of energy of the wavefield in the randomly layered media, wave beam propagation in random parabolic waveguides and diffusing tracers in random velocity fields.

Another example of such phenomena is the appearence of certain type singularities in the dynamics of individual realizations and their absence in the statistical description. Such models are often reduced to boundary value problems for the corresponding Fokker-Planck equations. We give other examples of those features of statistical solutions like the mean exponential divergence of the geometric-optical rays in a random medium vs. almost sure existence of caustics on finite distances and the phase fluctuations of the plane waves in randomly layered medium.

11:30 am	**Ed Waymire** Oregon State University	On random cascades: Some rigorous results

Abstract: Random cascades comprise a class of random measures which arise in diverse connections; e.g. statistical turbulence, spatial rainfall, spin-glasses, continuous percolation, and certain interacting particle systems. By now they have already been discussed in various talks on the "multifractal" structure of certain physical phenomena; e.g. turbulence data. As usual in the interplay between physics and mathematics, one finds seemingly "sound physical principles" in the physics literature which are not easily established rigorously without careful formulation. The focus of this talk will be on precise mathematical foundations and some rigorous results. This, in turn, also leads to mathematical observations which help provide new insights and principles for data analysis.

Afternoon Session Chair: George Papanicolaou

1:30 pm	**Rene Carmona** UC Irvine	Probabilistic analysis of the heat equation with random boundary conditions
2:30 pm	**Robert Anderson** University of North Carolina	Limit theorems for one-dimensional random walk in a random environment

Abstract: We will discus all possible limit theorems with bifurcations. From one side, Sinai's example of strong trapping and on the other side, classical CLT (homogenization). Especially important will be Rost's vent model which has physical application to disordered semiconductor physics.

CURRENT IMA PARTICIPANTS

POSTDOCTORAL MEMBERS FOR 1993-94 PROGRAM YEAR

NAME	PREVIOUS/PRESENT INSTITUTION
Belsley, Eric David	Harvard University
Cowen, Lenore	(Fall, NSF Postdoc) MIT
Cvitanic, Jaksa	Columbia University
Fridman, Moshe	University of Pennsylvania
Gillman, David	Massachusetts Institute of Technology
Hildebrand, Martin	University of Michigan
Narayanan, Babu O.	Courant Institute, New York University
Seppalainen, Timo	Ohio State University
Zirbel, Craig L.	Princeton University

POSTDOCTORAL MEMBERSHIPS IN INDUSTRIAL MATHEMATICS FOR 1993-94 YEAR

NAME	PREVIOUS/PRESENT INSTITUTION
Bao, Gang	Rice University
Copeland, Mark A.	Clemson University
Donahue, Michael J.	IMA
Huntley, Douglas	Northwestern University
Solomonoff, Alex L.	Brown University
Sun, Pu	MIT
Zhang, B.Y.	University of Cincinnati

LONG-TERM VISITORS IN RESIDENCE

4 Weeks or Longer

Athreya, Krishna	Iowa State University	MAY 16 - JUN 17
Baxter, John	University of Minnesota	
Biggins, John	University of Sheffield	APR 7 - JUN 29
Borchers, Al	University of Minnesota	SEP 1 - JUN 30
Bramson, Maury	University of Wisconsin	JAN 1 - JUN 30
Chung, Dong Myung	Sogang University	FEB 23 - MAY 13
Cockburn, Bernardo	University of Minnesota	SEP 16 - JUN 15
Daskalopoulos, Panagiota	University of Minnesota	SEP 1 - JUN 30
Du, Ding-Zhu	University of Minnesota	SEP 20 - JUN 1
Edelman, Paul	University of Minnesota	SEP 1 - JUN 30
Fabes, Eugene	University of Minnesota	SEP 1 - JUN 30
Friedman, Avner	IMA	
Fristedt, Bert	University of Minnesota	
Geyer, Charles	University of Minnesota	SEP 1 - JUN 30
Goldman, Jay	University of Minnesota	
Gray, Larry	University of Minnesota	
Guetter, Art	Hamline University	FEB 1 - JUN 1
Holst, Lars K.	Royal Inst. of Technology, Sweden	NOV 14 - DEC 11
Horn, Mary Ann	University of Minnesota	SEP 1 - JUN 30
Hu, Yiming	Case Western Reserve University	JAN 18 - MAY 31
Jagers, Peter	Chalmers University of Technology	APR 4 - JUN 19
Jain, Naresh	University of Minnesota	
Jeon, Jong Woo	Seoul National University	SEP 1 - AUG 31 (94)
Krylov, N.	University of Minnesota	
Littman, Walter	University of Minnesota	
McClure, Peter	University of Manitoba	JAN 1 - DEC 15 (94)
Miller, Willard	IMA	
Nagaev, Sergei	Russian Academy of Sciences	JAN 7-APR 7,APR 30-MAY 6
Neuhauser, Claudia	University of Southern California	JAN 1 - JUN 30
Pliam, John	IMA	
Saichev, Aleksander	University of Nizhni-Russia	JAN 18 - MAY 31
Shaw, Frank	U of California-Riverside	SEP 1 (93) - DEC 31 (94)
Stanton, Dennis	University of Minnesota	
Steele, Michael J.	University of Pennsylvania	SEP 1 - JUN 30
Sudderth, William	University of Minnesota	
Vatutun, V.A.	Steklov Mathematical Institute	JUN 1 - JUN 30
Voth, Eric J.	University of Minnesota	DEC 22 - AUG 31
Woyczynski, Wojbor	Case Western Reserve University	JAN 18 - JUN 1
Zinger, Abram	Leningrad Inst. of Aviation Eng.	APR 18 - JUN 24

SHORT TERM AND WORKSHOP VISITORS IN RESIDENCE

Aki, Keiiti	University of Southern California	MAY 15 - MAY 21
Baxendale, Peter	U. of Southern California	MAY 15 - MAY 20
Bickel, Peter	UC Berkeley	MAY 1 - MAY 3
Biegler, Larry	Carnegie Mellon University	MAY 14 - MAY 15
Borucki, Leonard	Motorola	MAY 12 - MAY 13
Byrne, Charles L.	U. of Massachsetts-Lowell	APR 30 - MAY 7
Chigirinskaya, Yulia	Lab. de Meteorologie Dynamique	MAY 15 - MAY 20
Coleman, Tom	Cornell University	MAY 14 - MAY 15
Conn, Andrew	IBM	MAY 14 - MAY 15
Furlani, Ed	Eastman Kodak	MAY 26 - MAY 27
Geman, Stuart A.	Brown University	MAY 1 - MAY 6
Gidas, Basilis	Brown University	MAY 1 - MAY 6
Griffa, A.	University of Miami	MAY 15 - MAY 20
Gupta, Vijay	University of Colorado	MAY 15 - MAY 20
Herman, Gabor T.	University of Pennsylvania	MAY 1 - MAY 8
Holloway, Greg	Institute of Ocean Sciences, Canada	MAY 15 - MAY 20
Jelinek, Fred	Johns Hopkins University	MAY 4 - MAY 6
Ji, Chuanshu	University of North Carolina	MAY 1 - MAY 6
Juang, B.H. (Fred)	AT&T Bell Labs	MAY 1 - MAY 6
Klyaiskin, V.	Russian Academy of Sciences	MAY 15 - MAY 20
Kogan, Joseph	Courant Institute	MAY 1 - MAY 8
Lee, Chin-Hui	AT&T Bell Labs	APR 30 - MAY 6
Levinson, Steve	AT&¿T Bell Labs	MAY 2 - MAY 6
Lovejoy, Shaun	McGill University	MAY 15 - MAY 20
Maar, James R.	National Security Agency	MAY 1 - MAY 6
Mark, Kevin	Washington University	MAY 1 - MAY 6
Mazza, Christian	University of Fribourg	APR 30 - MAY 5
Miller, Mike	Washington University	MAY 1 - MAY 6
Molchanov, Ilya S.	University of North Carolina	MAY 15 - MAY 25
Muller, Peter	University of Hawaii	MAY 14 - MAY 21
Nagaev, Sergei	Russian Academy of Sciences	JAN 2-MAR 31,APR 30-MAY 6
Naud, Catherine	Lab. de Meteorologie Dynamique	MAY 15 - MAY 20
Papanicolaou, George	Stanford University	MAY 15 - MAY 20
Piterbarg, Leonid	University of Southern California	MAY 15 - MAY 21
Rosenblatt, Murray	UC San Diego	MAY 16 - MAY 22
Rozovskii, B.	U. of Southern California	MAY 15 - MAY 20
Santosa, Fadil	University of Delaware	MAY 14 - MAY 15
Schertzer, Daniel	Lab. de Meteorologie Dynamique	MAY 15 - MAY 20
Shepp, Larry	AT&T Bell Labs	MAY 1 - MAY 6
Smith, Richard	University of North Carolina	MAY 14 - MAY 18
Sondhi, Mohan	AT&T Bell Labs	APR 30 - MAY 6
Sun, Don X.	SUNY-Stony Brook	MAY 1 - MAY 6
Surgailis, Donatas G.	Lithuanian Academy of Sciences	MAY 9 - MAY 20
Vardi, Yehuda	Rutgers University	MAY 1 - MAY 6
Vergassola, Massimo	CNRS	MAY 15 - MAY 20
Villarubi, Roberto	University of Maryland	MAY 15 - MAY 20
Waymire, E.	Oregon State University	MAY 15 - MAY 20
Weichman, P.	Caltech	MAY 15 - MAY 20
White, Benjamin S.	Exxon	MAY 15 - MAY 20
Yaglom, A.M.	MIT	MAY 15 - MAY 20